LONG-RANGE TRIAGE:
ASSESSING PATIENT RISK FROM A DISTANCE

David Anderson, Mangla Gulati, Bruce Golden, Ed Wasil, et al.

University of Maryland

College Park & Baltimore, MD

INFORMS Annual Meeting, October 2013

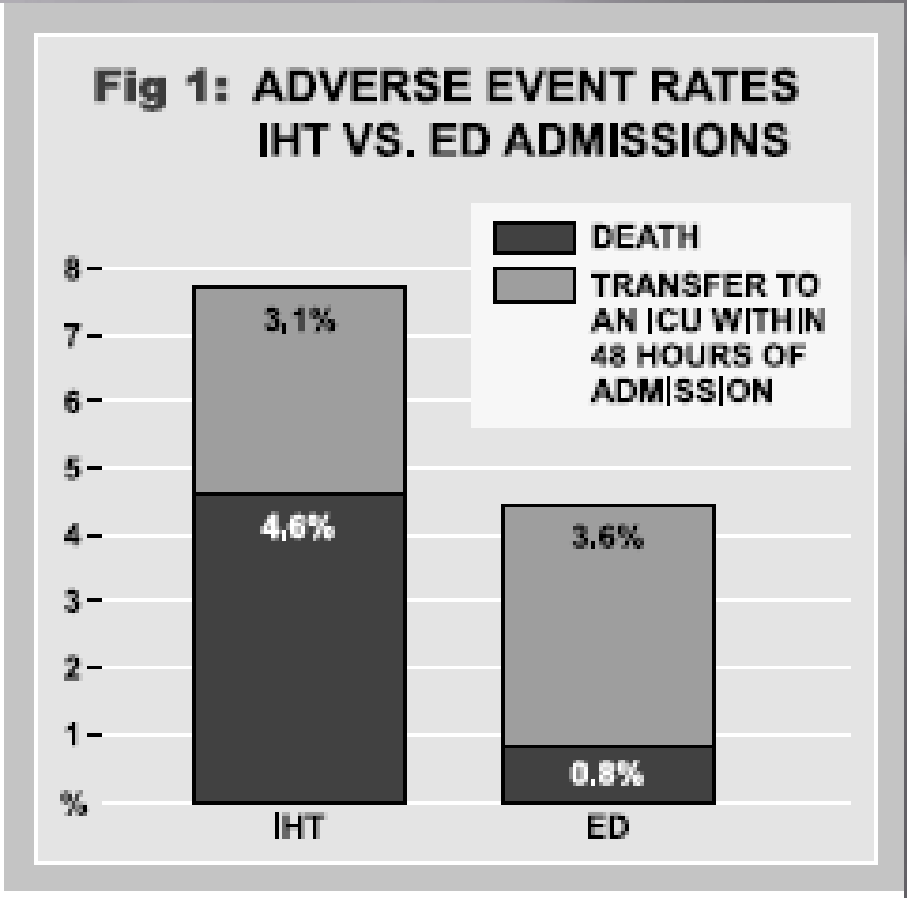
Internal Medicine

- Broad range of diseases
- Patients often transferred to/from ICU
- Treated at UMMC by hospitalists

Inter-Hospital Transfer (IHT)

- Some patients too severe for smaller hospitals
- UMMC often accepts these patients
- IHT patients tend to be higher acuity

Higher Severity



- These patients put a strain on hospital resources
  - ICU space
  - Nurse time
- Uncertainty in referring hospital's assessment
  - Poor documentation
  - Incomplete/inaccurate information

Objective Risk Assessment

- Better patient severity information needed
- Referring hospitals not always trusted
- Ideal tool is:
  - Objective
  - Easy to understand
  - Based on commonly used patient data
  - Quick to compute

Data

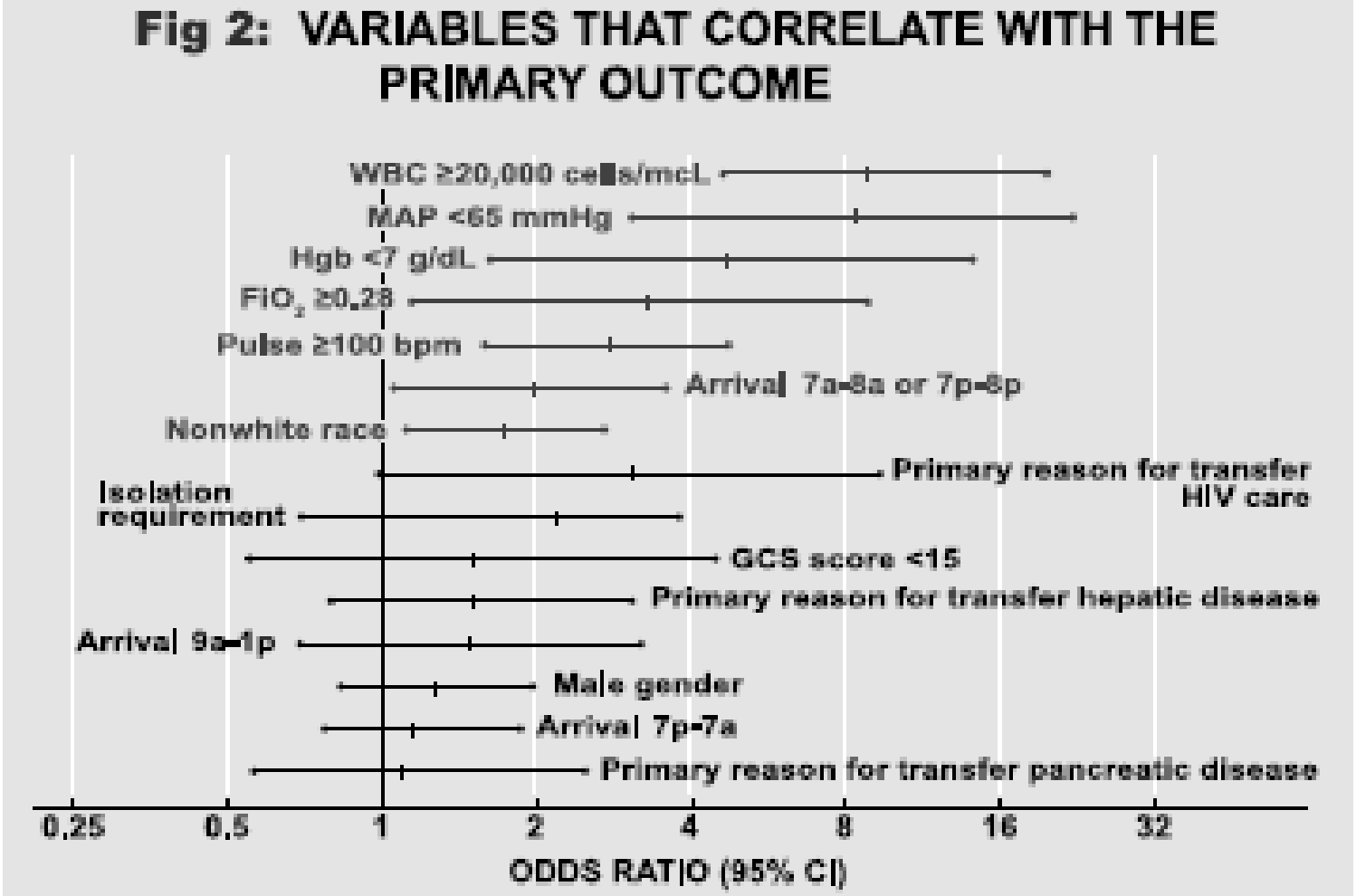
- 1158 Inter-Hospital Transfer patients
- Demographic and medicinal information
- Outcome information
  - Death
  - ICU within 48 hours

Patient Demographics

Table 1: PATIENT DEMOGRAPHICS

Women, %	49.2
Self-identified race or ethnic group, %	
Non-Hispanic white	61.1
Non-Hispanic black	25.8
Hispanic	1.6
Asian/Pacific Islander	2.1
Other	9.5
Age (mean 55), %	
80+	12.3
60–79	30.3
40–59	36.4
<40	21.0
BMI (mean 30.1), %	
Underweight (<18.5)	6.1
Normal (18.5–25)	32.7
Overweight (25–30)	23.2
Obese (30–35)	17.9
Severely obese (≥35)	20.0
Primary Reason for Transfer, %	
Gastroenterologic Care	**61.9**
Pulmonary Care	6.0
Hematologic Care	4.8
Human Immunodeficiency Virus Care	2.5
Dermatologic or Rheumatologic Care	1.2
Neurological Care	1.2
Other Specialty Care	22.4

Individual Factors



Initial HALT Tool

Table 2: THE HALT PREDICTION TOOL

Criterion	Definition	Prevalence
Hypotension	Mean arterial pressure <65 mmHg	1.5%
Anemia	Hemoglobin <7 g/dL	1.5%
Leukocytosis	White blood cell count ≥20,000 cells/mcL	4.1%
Tachycardia	Pulse ≥100 beats per minute	8.2%

Patients with one or more of these criteria at time of transfer were five times more likely to suffer an adverse event after arrival to a low level of care at the tertiary care center than were patients with none of these criteria. Blood pressure and hemoglobin cutoffs were chosen based on literature-supported thresholds for vasopressor use[4] and blood transfusion[5].

Description of HALT

Feature	Description
Hypotension	Measured by mean arterial pressure. Considered low if < 65 mmHg.
Anemia	Measured by hemoglobin. Considered low if < 7 g/dL.
Leukocytosis	Measured by white blood cell count. Considered high if > 20,000 cells/mL.
Tachycardia	Measured by pulse. Considered high if > 100 beats per minute.

Methods

- Binary Cutoff Model
  - Simple, intuitive
- Logistic Regression
  - Easy to interpret, better power
- Naïve Bayes
  - Slightly better results, more complicated
- Combination of logistic regression and Naïve Bayes

Results

	Predicted 0	1
Observed 0	.807	.048
1	.110	.034

HALT Binary Cutoff

	Predicted 0	1
Observed 0	.807	.038
1	.113	.042

Logistic Regression

	Predicted 0	1
Observed 0	.813	.038
1	.108	.042

Naïve Bayes Classifier

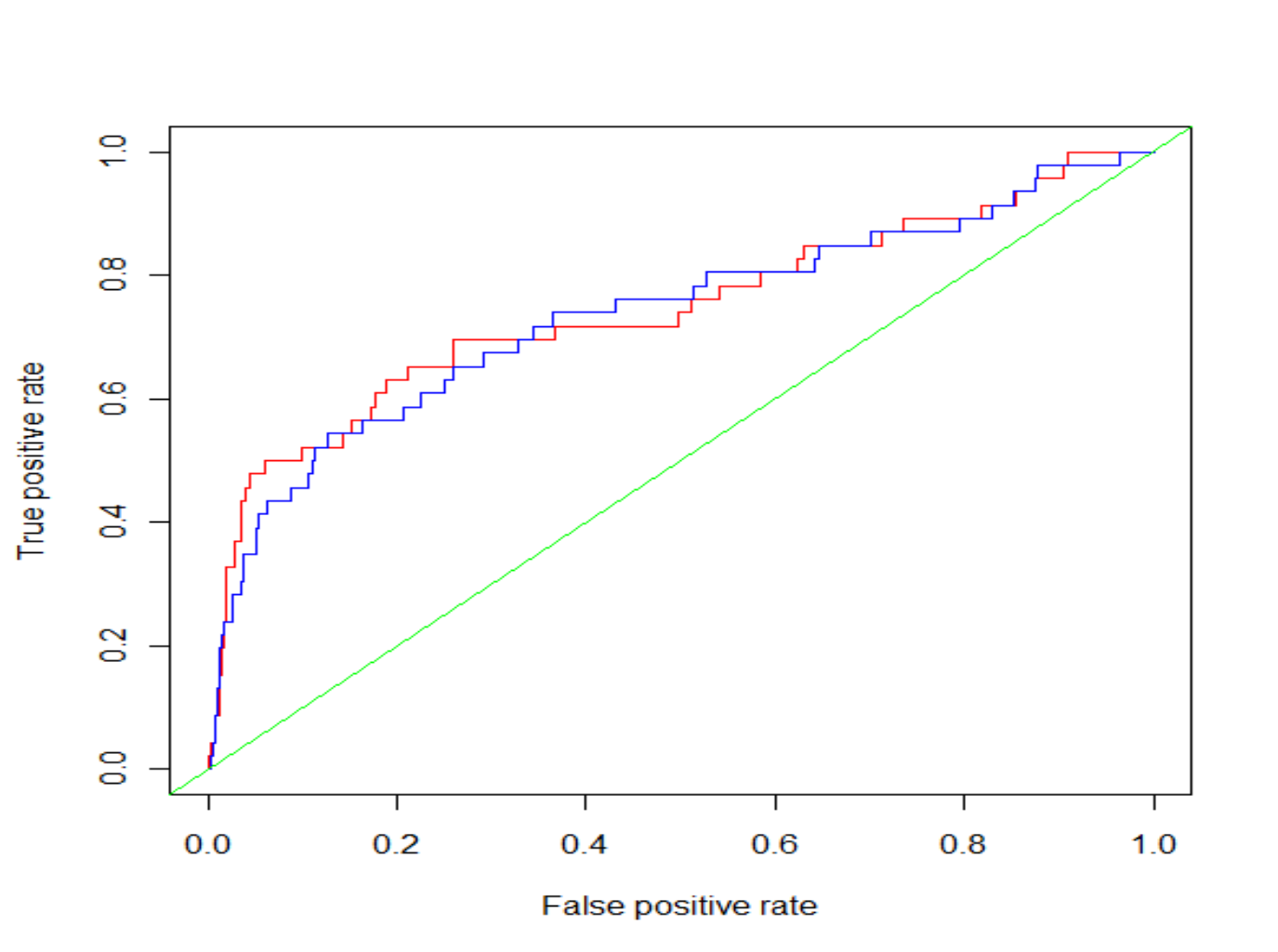
	Predicted 0	1
Observed 0	.781	.033
1	.139	.047

Combination Tool

Results

Tool	True +	True -	False +	False -	Sensitivity	Specificity
Max	27	450	80	19	0.587	0.849
Logistic Regression	24	465	65	22	0.522	0.877
Naïve Bayes	24	468	62	22	0.522	0.883
HALT	39	935	128	56	0.411	0.88
HLT	37	946	117	58	0.39	0.89
ALT	35	947	116	60	0.368	0.891
LT	33	958	105	62	0.347	0.901
HAL	29	1010	53	66	0.305	0.95
HAT	25	962	101	70	0.263	0.905

ROC



ROC plots for Naïve Bayes (Red) and Logistic Regression (Blue)

False Positives vs. False Negatives

Model	Cost 1:1	Cost 3:1	Cost 5:1	Cost 10:1	Cost 20:1	Cost 50:1	Cost 100:1
Combination	0.172	0.238	0.304	**0.469**	**0.799**	**1.788**	**3.438**
Naïve Bayes	0.146	0.222	**0.299**	0.49	0.872	2.017	3.927
Logistic Regression	0.151	0.227	0.304	0.495	0.877	2.023	3.932
HALT	0.159	0.256	0.352	0.594	1.078	2.529	4.947
HLT	0.151	0.251	0.352	0.602	1.103	2.605	5.11
HAL	**0.103**	**0.217**	0.331	0.616	1.186	2.896	5.745
ALT	0.152	0.256	0.359	0.618	1.136	2.691	5.282
LT	0.144	0.251	0.358	0.626	1.162	2.768	5.445
HAT	0.148	0.269	0.39	0.692	1.296	3.11	6.132

Including Age

	Actual 0	Actual 1
Extended Logit 0	434	19
Extended Logit 1	59	22

The sensitivity of the model increases from 52.2% to 53.7%, while the specificity increases from 87.7% to 88.0%. This translates to a decrease in "cost" of between 3.3% (1:1 ratio) and 6.7% (100:1 ratio).

Prospective Study

- Currently collecting data for a prospective study
- 34 patients treated so far
- 6 classified as High Risk
  - 4 Discharged Home
  - 1 Died
  - 1 Transferred to a Skilled Nursing Facility
- 28 classified as Low Risk
  - 26 discharged home
  - 1 ICU stay – colonoscopy perforated bowel
  - 1 transfer back to referring hospital

Conclusions

- Simple, objective measures can be used to accurately predict risk
- This research will lead to a useful tool in helping to make admission decisions and predict resource usage

Future Work

- We hope to implement the HALT tool as a standard part of the IHT process
- Better information about incoming patients
- Better resource management and utilization

Questions?

danderson@rhsmith.umd.edu